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Substrates based on carbonized rice husk alter strawberry productivity in a semi-hydroponic system

Substratos à base de casca de arroz carbonizada alteram a produtividade do morango em sistema semi-hidropônico

Sustratos a base de cascarilla de arroz carbonizada alteran la productividad de la fresa en un sistema semihidropónico

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Marcos Vinícius Marques Pinheiro*
ORCID: https://orcid.org/0000-0002-5028-7818
Universidade Estadual do Maranhão, Brasil.
E-mail: macvini@gmail.com
Evandro Holz
ORCID: https://orcid.org/0000-0002-8018-6743
Universidade Federal de Santa Maria, Brasil
E-mail: evandro_holz29@hotmail.com
Anderson Rafael Webler
ORCID: https://orcid.org/0000-0003-0744-4694
Universidade Federal de Santa Maria, Brasil
E-mail: anderson.webler@gmail.com
Guilherme Masarro-Araujo
ORCID: https://orcid.org/0000-0001-9189-8917
Universidade Federal de Santa Maria, Brasil
E-mail: guilhermemasarroaraujo@gmail.com
Leonardo Antonio Thiesen
ORCID: https://orcid.org/0000-0002-3439-842X
Universidade Federal de Santa Maria, Brasil.
E-mail: thiesen07@hotmail.com
Fábio Miguel Knapp
ORCID: https://orcid.org/0000-0002-9964-1101
Universidade Federal de Goiás, Brasil.
E-mail: fabio.knapp@hotmail.com
Maria Inês Diel
ORCID: https://orcid.org/0000-0002-7905-2166
Universidade Federal do Pampa, Brasil
Email: mariaines.diel@hotmail.com
Denise Schmidt
ORCID: https://orcid.org/0000-0002-9963-4956
Universidade Federal de Santa Maria, Brasil
E-mail: denise@ufsm.br

Abstract
The production of strawberry in the semi-hydroponic system still has several unknowns to be answered, one of them is to make the system less costly because this crop has a high implementation cost. The choice of the ideal substrate is one of the biggest doubts of the producer, as it can generate high costs when purchased commercially. For this, rice husk becomes an alternative to replace other substrates because it is an easily available and inexpensive material in rice regions of Brazil. The objective of this work was to evaluate and compare the productive performance of strawberry cv. Albion cultivated in different substrate compositions under the semi-hydroponic system. The exclusive use of charred rice husk was not beneficial because it reduced growth variables and crop yield. In the production of strawberry cv. Albion in polypropylene gutter system, the use of 25% commercial substrate amount is enough to maintain the productivity and quality of pseudofruits, in addition to further reducing the system implementation costs by using charred rice husk as substrate constituent. Include the abstract in English.
Keywords: Fertigation; *Fragaria X ananassa*; Gutters.

Resumo
A produção do morangueiro em sistema semi-hidropônico ainda apresenta várias incógnitas a serem respondidas, uma delas é tornar o sistema menos oneroso, pois este cultivo apresenta elevado custo de implantação. A escolha do

substrato ideal é uma das maiores dúvidas do produtor, pois pode gerar custos elevados quando adquiridos comercialmente. Assim, a casca de arroz torna-se alternativa para substituir outros substratos por ser material facilmente disponível e de baixo custo em regiões orizícolas do Brasil. O objetivo deste trabalho foi avaliar e comparar o desempenho produtivo de morangueiro cv. Albion cultivado em diferentes composições de substratos sob sistema semi-hidropônico. A utilização exclusiva de casca de arroz carbonizada não se mostrou vantajosa, pois reduziu variáveis de crescimento e produtividade da cultura. Na produção do morangueiro em sistema de calhas de polipropileno, a utilização da quantidade de 25% substrato comercial é suficiente para manter os resultados produtivos e a qualidade dos pseudofrutos, além de reduzir os gastos de implantação do sistema, utilizando casca de arroz carbonizada como constituinte do substrato.
Palavras-chave: Fertirrigação; Fragaria ananassa; Calhas de polipropileno com fundo falso.

Resumen
La producción de fresa en sistema semihidropónico aún tiene varias incógnitas por responder, una de ellas es abaratar el costo del sistema debido a que este cultivo tiene un alto costo de implementación. La elección del sustrato ideal es una de las mayores dudas del productor, ya que puede generar altos costos cuando se compra comercialmente. Por eso, la cascarilla de arroz se convierte en una alternativa para sustituir otros sustratos por ser un material de fácil disponibilidad y bajo costo en las regiones arroceras de Brasil. El objetivo de este trabajo fue evaluar y comparar el comportamiento productivo de fresa cv. Albion cultivada en diferentes composiciones de sustrato bajo el sistema semi-hidropónico. El uso exclusivo de cascarilla de arroz carbonizada no fue beneficioso porque redujo las variables de crecimiento y el rendimiento del cultivo. En la producción de fresa cv. Albion en sistema de canalones de polipropileno, el uso de 25% de sustrato comercial es suficiente para mantener la productividad y calidad de los pseudofrutos, además de reducir aún más los costos de implementación del sistema al utilizar cascarilla de arroz carbonizada como componente del sustrato.
Palabras clave: Fertirrigación; *Fragaria* × *ananassa*; Canalones.

1. Introduction

Strawberry (*Fragaria X ananassa*) is a crop that has high economic and social importance because it brings high productivity by area and contributes to the permanence of families of small producers in the field (Diel, 2016). On a commercial scale, the semi-hydroponic system is the main cultivation technique without soil in the world (Pardossi et al., 2011). This is justified by the easiness of handling provided by the benches above ground level, facilitating the worker's ergometry and reducing the incidence of diseases that affect culture, such as nematodes, fungi, and bacteria (Zorzeto, 2011).

The cultivation of strawberries in a semi-hydroponic system presents many obstacles to be solved, among them making the system less expensive, as this cultivation has a high implantation cost. The choice of substrate is one of the biggest challenges for the system because when purchased commercially, it requires a high investment from the producer. In this way, the use of organic waste becomes an alternative to reduce expenses with the implementation of culture in a semi-hydroponic system (Diel et al., 2016a). Even so, it is sought not only the low cost but also substrates with good physical characteristics that allow adequate retention of water and air, in addition to good availability of the nutrient solution, generating the optimal development of the plants (Medeiros et al., 2008). Several types of compounds can be used, with emphasis on carbonized rice husk, sugarcane bagasse, pine husk, organic compounds, peat, and vermiculite, in addition to mixtures in different percentages of these compounds (Melo et al., 2006; Diel et al., 2018).

Because it is an easily available and low-cost material in rice fields, rice husk is a well-studied resource to replace other substrates, and for this reason, it is the most widely used substrate in southern Brazil for strawberry cultivation (Tsakaldimi, 2006; Gimenez et al., 2008; Freitas et al., 2013). The carbonized rice husk has the advantages of presenting physical and chemical stability, like this, it is able to resist decomposition, allowing the use of more than one strawberry cultivation cycle (Melo et al., 2006). Considering this information, it is herein hypothesized that the use of different compositions of substrates under a semi-hydroponic system in false bottom polypropylene gutters could further optimize the productive performance of strawberry cv. Albion.

In this study, we describe a way in which different substrate and carbonized rice husk compositions improve the productive performance of strawberry (*Fragaria X ananassa*) cv. Albion during the cycle on days after transplantation under a semi-hydroponic system in false bottom polypropylene gutters. For this, the characteristics of growth, evaluations of photosynthetic pigments, and quality of the fruits are reported and discussed. The elucidation and correlation of these factors are essential for understanding the behavior of plants on the different substrates used in a semi-hydroponic system associated with the production cycle of the crop.

2. Methodology

The experiment was carried out in the experimental area of the Federal University of Santa Maria, Frederico Westphalen *Campus* – Rio Grande do Sul, Brazil, located at 27º23'S, 53º25'O, in a galvanized steel greenhouse with an arc roof, with dimensions of 10 m wide and 20 m long. For the cultivation of strawberry plants, 5-meter of false bottom polypropylene gutters (Hidrogood®; https://hidrogood.com.br) with small openings were used for drainage and return of the irrigation solution, being maintained on benches 1 meter high from the ground (Figure 1). Strawberries were planted on June 20, 2018, and the experiment was conducted until January 16, 2019.

Figure 1 - Semi-hydroponic system in five-meter of false bottom polypropylene gutters (A) with different compositions of carbonized rice husk and H-Decker® substrate (B and C) and closed fertigation system in strawberry cv. Albion (C and D).

Fonte: Authors.

In this semi-hydroponic system, the strawberry plants cultivar Albion was grown. The plants came from Agudo - RS. The filling of the gutters with the substrate was carried out with different percentages of the mixture of carbonized rice husk and commercial substrate H-Decker® based on pine husk and vermiculite, keeping the strawberry plants at 16 cm spacing.

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The irrigation system was installed with a pump, water tank, pipes, and drip tapes with emitters spaced 0.15 m apart. Fertigation was applied with the use of a timer for automatic activation, and the frequency of irrigations was adapted according to the evapotranspiration of the plants. The nutrient solution was used following the formulation recommended by Bortolozzo et al. (2007) and managed to keep the pH and electrical conductivity constant (approximately 6.0 and 1.5 $dS.m^{-1}$, respectively).

The maximum and minimum air temperatures were monitored throughout the cultivation cycle using a digital thermometer inside the greenhouse, being kept close to the height of the plants, with daily data collection. To obtain the average air temperature, the equation was used:

$$T.avg = \frac{(T.\max + T.\min)}{2}$$

Where: T. avg. = average temperature; T. max = maximum temperature; T. min = minimum temperature.

To better develop the plants, the inflorescences were removed in the first 40 days after transplantation. In addition, the runner tips and senescent leaves were routinely removed throughout the growing cycle.

The experiment was conducted in a randomized block design, in a 5x5 factorial scheme, with five substrate compositions and five evaluations during the cycle on equidistant days after transplantation (DAT), with four replicates each, with the experimental unit being composed of a plant. For the leaf area variable, the RBD was performed, in a 5x7 factorial scheme, with five substrate compositions and seven DAT, with four repetitions and the experimental unit composed of a plant, performing two more DAT to accompany the initial growth of the plants before the reproductive phase.

The treatments (substrate compositions) used were: T1 – 100% carbonized rice husk; T2 – 75% carbonized rice husk + 25% commercial substrate H-Decker®; T3 – 50% carbonized rice husk + 50% commercial substrate; T4 – 25% carbonized rice husk + 75% commercial substrate; and T5 – 100% commercial substrate. The standardized DAT for the evaluations were: DAT30 – 07/20/2018; DAT60 – 08/19/18; DAT 90 – 18/09/18; DAT120 – 10/18/18; DAT150 – 11/17/18; DAT180 – 12/17/18 and DAT 210 – 01/16/19.

The production variables were analyzed during the entire reproductive phase, making three harvests per week, evaluating the following variables: fruit production per plant (FPP), number of fruits per plant (NFP), and average fruit mass (AFM). For qualitative factors of pseudofruits, the content of soluble solids (SS) and titratable acidity (TA) were evaluated monthly. The SS content was evaluated using a portable refractometer and the TA was evaluated using phenolphthalein as an indicator and titrated with (NaOH) 0.1 N. The result was calculated in citric acid equivalence.

The leaf area (LA) was obtained from evaluations every 30 days, using a method of estimating the strawberry leaf area calculated by the relation between the measures of length and width of the central leaflet leaf, following the methodology of Pires et al. (1999) made from measurements of the length and width of the central leaflet of all leaves of each plant.

To obtain the mathematical model, 216 leaves were collected, fully expanded, healthy, of different ages and sizes, randomly between plants and treatments. The collected leaves were measured, scanned and the images processed using the ImageJ software to obtain the leaf area of each leaf. The results were obtained after performing a multicollinearity test, which demonstrated low collinearity between length and width, thus using the two values to fit the linear mathematical model, in which the multiplication ratio between the width and the length of the central leaflet showed a greater degree of similarity to the obtained leaf area data.

The following model was obtained: $y = 1{,}9553x + 4{,}4361$ R^2: 0,90.

Where x represents the product between the length and width of the central leaflet of the leaf.

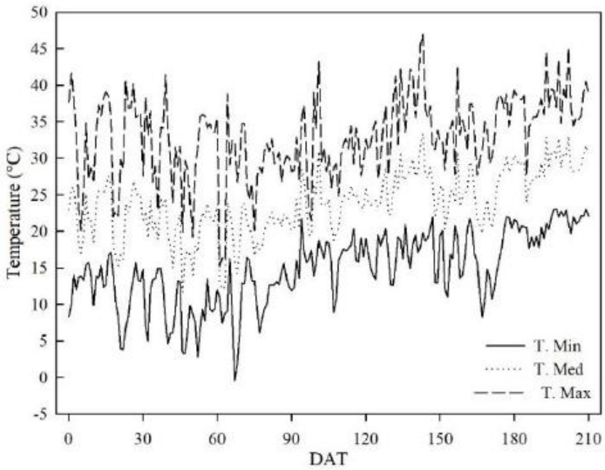
For the evaluation of photosynthetic pigments, non-destructive evaluations were performed using a digital chlorophyll meter (ChlorofiLOG®, model CFL 1030), with chlorophyll *a* (Chl *a*), chlorophyll *b* (Chl *b*), and total chlorophyll (ChlT) being evaluated. The samplings were obtained from the second leaf of the apex towards the base, the evaluations were carried out every 30 days considering the transplant date and weather conditions at the time of Reading, with totally clear days.

The data were submitted to the analysis of normality by the Shapiro-Wilk test, and submitted to variance analysis and, when significant, the qualitative data were compared using the Scott-Knott test at 5% significance. The quantitative data of the variables of production, leaf area, and photosynthetic pigments were divided into periods of 30 days, according to the DAT and submitted to regression to analyze the temporal distribution of these variables, using the statistical program SISVAR (Ferreira, 2011).

3. Results and Discussion

During the experimental period, the air temperature inside the greenhouse registered minimum temperatures of -0.4°C and a maximum of 47°C (Figure 2). Air temperature is directly related to fruit quality and final production (Krüger et al., 2012). The ideal temperature for fruiting is around 18-24°C, causing inhibition of flowering above 32°C, causing floral abortion (Ronque, 1998).

Figure 2 - Minimum, average, and maximum temperatures inside the greenhouse in strawberry cv. Albion, during the days after transplant (DAT30 – 20/07/2018; DAT60 – 19/08/18; DAT90 – 18/09/18; DAT120 – 18/10/18; DAT150 – 17/11/18; DAT180 – 17/12/18 e DAT210 – 16/01/19).

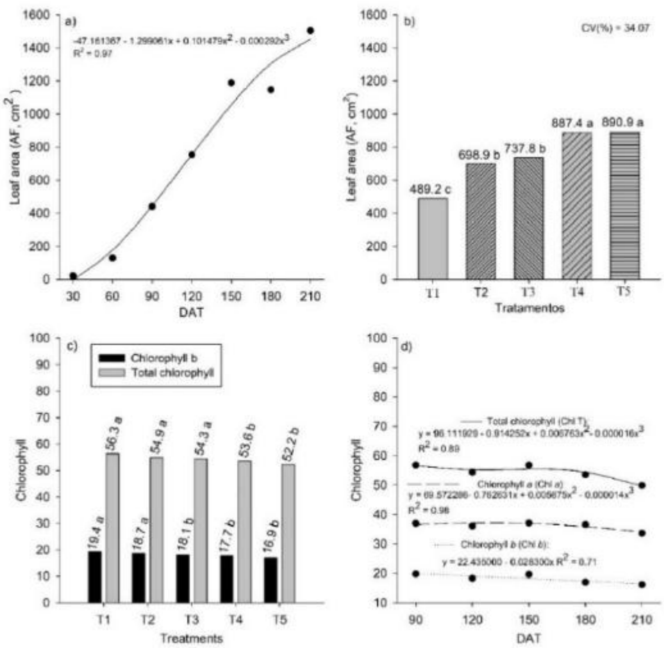


Fonte: Authors.

From the analysis of variance, the qualitative factors of the pseudofruits (SS and TA) did not differ significantly, by the F test ($p > 0.05$). The variables LA, Chl *b*, Chl T and FPP differed significantly for the different substrates and DAT, with no significant interaction between them. The variables Chl *a* and AMF showed no difference between the different substrates, differing significantly only for DAT and the variable NPF differed only for the different substrates.

For the variable LA when related to the DAT, the regression that best fit during the cycle was the cubic, showing increasing values of LA from 30 DAT to 150 DAT, showing a slight downward trend in 180 DAT, however, increasing again until the 210 DAT, reaching a maximum value of 1500 cm^2 at the end of the cycle (Figure 3A). The highest concentrations of commercial substrate, T5, and T4, resulted in higher LA values, 890.9 and 887 cm^2, respectively. The lowest values were obtained in the T1 that presented exclusively rice husk, with 489.2 cm^2 (Figure 3B). This lower production of LA in T1 can be explained by the greater porosity and aeration space of the carbonized rice husk, which reduces the water retention capacity and plant growth due to water deficiencies, capable of occurring on days of high temperatures (Zorzeto et al., 2014).

Figure 3 - Leaf area (LA, cm^2) of strawberry cv. Albion in relation to the days after transplantation (DAT) (a) and different substrate compositions (b). Chlorophyll *b* (Chl *b*) and Total chlorophyll (Chl T) in different substrate compositions (c) and Chlorophyll *a* (Chl *a*), chlorophyll *b* (Chl *b*) and total chlorophyll (Chl T) (d) depending on the DAT. (T1 – 100% carbonized rice husk; T2 – 75% carbonized rice husk + 25% commercial substrate; T3 – 50% carbonized rice husk + 50% commercial substrate; T4 – 25% rice husk carbonized rice + 75% commercial substrate, and T5 – 100% commercial substrate). Means followed by the same letter do not differ by the Skott-Knott test at 5% significance.



Fonte: Authors.

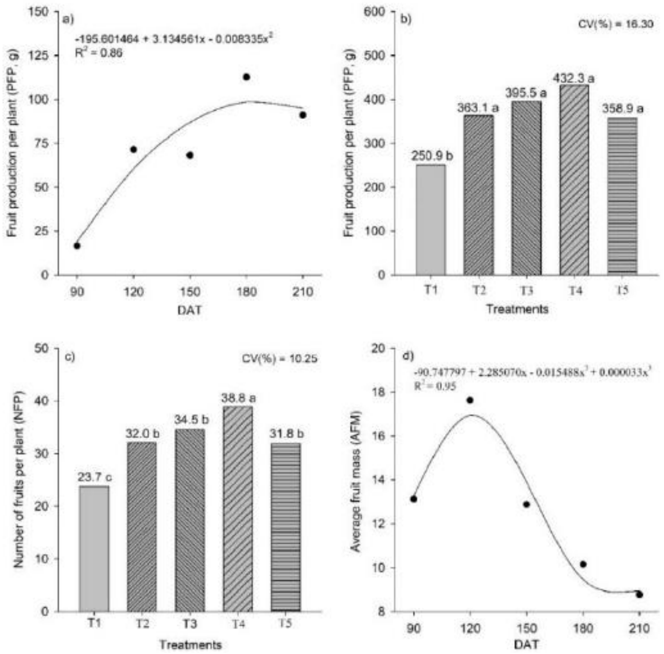
The variable Chl *b* showed higher values in T1 and T2 (Figure 3C). For Chl T, T1, T2, and T3 were significantly higher, as well as for Chl *b*, the substrates with a greater volume of rice husk showed statistical superiority in relation to T4 and T5. These results are due to the greater water retention capacity in the substrates with the highest concentration of commercial substrate. There is a reduction in the values of chlorophyll in plants grown in soils or substrates with a greater amount of available water due to the increase in the concentration of free radicals that destroy them (Drew, 1997). As a result, substrates with a higher proportion of rice husk and, consequently, less moisture due to porosity and low water retention, favored the increase in chlorophylls, not degrading them.

During the strawberry cultivation cycle, for Chl *a* and Chl T, the equation that best fit was the cubic one, presenting high values at the beginning of the cycle until 150 DAT, decreasing their values until the end of the cycle (Figure 3D). For Chl *b*, the equation that best fitted was the linear one, showing a reduction with the passing of the days after the transplant.

This reduction in the values of Chl *a*, Chl *b* e Chl T in plants during the strawberry cycle may be related to the reproductive period and the peak of fruit production in 180 DAT, requiring greater nitrogen demand for fruit growth and maturation, compared to the vegetative growth that occurs simultaneously in the plant (Godoy et al., 2008). The effect of increasing the levels of chlorophyll in the leaf caused by the use of red fluorescent caused an inverse effect in the production of pseudofruits for the cultivar Camarosa found by Machado et al. (2018), that is, showing the inverse proportion between the levels of chlorophylls and the production of strawberry pseudofruits. Several studies have already been carried out showing the positive correlation between the levels of chlorophyll and nitrogen in the leaves, of the most varied crops, such as corn (Chapman & Barreto, 1997) and cotton (Malavolta et al., 2004). Another factor that may have led to this reduction in chlorophyll contents over the course of the cycle is the variation in solar irradiance, as with the passage of the cycle and the proximity of the summer season, in 180 DAT, there is an increase in solar irradiation which it favors the availability of light and therefore requires less chlorophyll production (Godoy et al., 2008).

For FPP, the equation that best fit during the strawberry cycle was quadratic regression, showing a successive increase from 90 DAT to 180 DAT when the plants produced 112.7 g monthly, and reducing by 210 DAT to 91.13 g (Figure 4A). The treatment that was shown to be superior in relation to FPP was T4 (25% carbonized rice husk + 75% commercial substrate), producing 432.4 g, however, differing significantly only from T1 which produced 250 g (Figure 4B). The same occurred for the variable NFP, in which it was possible to observe that T4 was superior when compared to the others, presenting an average of 38.9 fruits/plant, thus also justifying the highest FPP. The lower values were also obtained at T1, with 23.8 fruits/plant (Figure 4C).

Figure 4 - Fruit production per plant (FPP) depending on the days after transplantation (DAT) (a) and depending on the treatments (substrate compositions) in production (b). Number of fruits per plant (NFP) as a function of treatments (c) and average fruit mass (AFM) as a function of the days after transplantation (DAT) of strawberry cv. Albion (d). (T1 – 100% carbonized rice husk; T2 – 75% carbonized rice husk + 25% commercial substrate; T3 – 50% carbonized rice husk + 50% commercial substrate; T4 – 25% rice husk carbonized rice + 75% commercial substrate, and T5 – 100% commercial substrate). Means followed by the same letter do not differ by the Skott-Knott test at 5% significance.



Fonte: Authors.

In FPP and NFP, the lower results found for T1 may be related to the use of rice husk without mixtures with a substrate. Zorzeto et al. (2014) observed that substrate with rice husk used in isolation showed zero values of easily available water, thus compromising the good development of strawberry plants, which makes the mixture of compounds interesting to use in a semi-hydroponic strawberry system, demonstrating that the exclusive use of rice husk in order to reduce costs must be carefully analyzed. When testing organic compounds in strawberry cultivation, Diel et al. (2016b) concluded that the mixture of carbonized rice husk and organic compost provided the best water use efficiency and, consequently, greater productivity in the crop.

The regression that best fit for AFM was cubic, with the highest AFM at the beginning of the harvest at DAT 120 (17.6g), followed by a reduction at DAT 210, in which values of 8.77g can be observed (Figure 4D). These values are similar to those of Silva et al. (2015) who, when studying three cultivars, found that there was a reduction in fruit size and weight throughout the strawberry crop cycle. In some strawberry cultivars, the first flowering produces larger fruits, with a fresh mass up to three times greater compared to the plants of the next flowering (Ronque, 1998). Another factor related to these results is the increase in temperatures from DAT 120 (Figure 2), since according to Wang and Camp (2000), temperatures above 30°C end up reducing the size and weight of strawberry fruits.

4. Final Considerations

Thus, to produce strawberry cv. Albion in polypropylene gutter system, the most suitable substrate to maintain productivity is 25% carbonized rice husk and 75% commercial H-Decker® substrate. However, the use of only 25% of commercial substrate H-Decker® and 75% of carbonized rice husk is enough to maintain good productive results and generate cost reduction in the implementation of the system, since the carbonized rice husk is a product of easy commercial acquisition and low cost in rice growing regions of Brazil.

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